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Space-angle Signal Processing Using a Modulated Scatter Array

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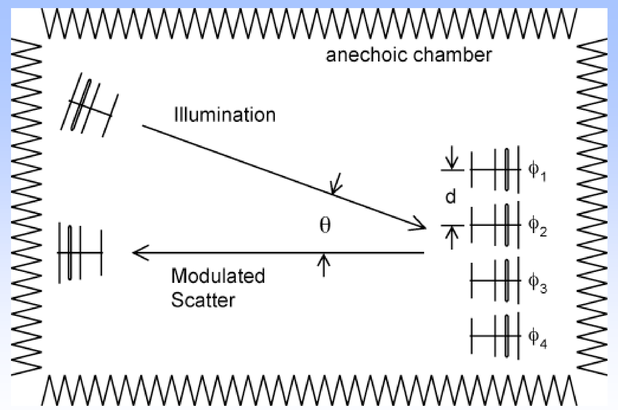

Fig. 1. Geometry and approximate scale drawing of the 4 element array, illumination CW source, and receive antenna in the anechoic chamber.

Abstract

A UHF signal processing technique is described in the Fourier Space-Angle domain that uses an array of scattering elements with reflection coefficients modulated at baseband. The illumination arrival angle distributes a UHF phase across the array, and the baseband modulator phase at each of the array elements determines the radiation angle of the desired scattered product. Undesired products are re-radiated in different directions. Example 1, 2 and 4 element arrays operate at 432 MHz array with 700 Hz modulation. 2 element arrays cancel one sideband, and the 4 element array cancels both the undesired sideband and 2nd order products. Reflection coefficient modulation uses slow electronics, and scattered signals are summed in space, so this technique is attractive at much higher frequencies.

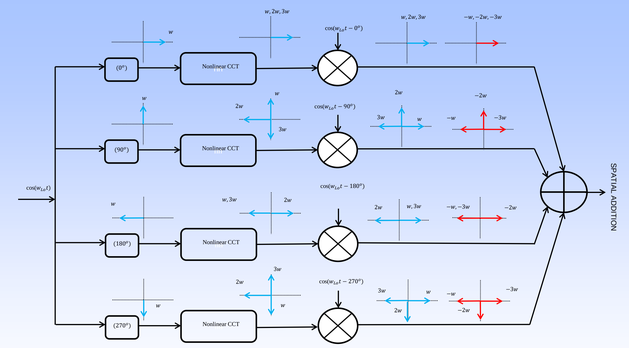

Fig. 2. 4-path circuit using antenna locations as phase shifter.

I. Theoretical Background

Spatial diversity-frequency diversity transformation is a process to assign an angular scattered beam in the space for each different frequency, requiring a multi-frequency generator and a multi antenna radiator (antenna) array. Referring to Figure 1, a CW signal at 432MHz illuminates the array, arriving at an angle Θ. The relative distributed phase among antenna elements is related to element spacing d and arrival angle Θ. The induced signal will be modulated by 700Hz sine wave signal at the RF diode switches, leading into intermodulation distortion generation IMD due to inherited nonlinearities in semiconductor devices.

$$y(t)=a1\ x^{}(t)+a2\ x^{2}(t)+a3\ x^{3}(t)+a4\ x^{4}(t)+\cdots$$

The input signal consists of two tones the illuminated and the modulating signals, and the output signal will have the desired IMD ones and undesired products. Antenna array works to cancel or boost the specific frequency-angular scattered beam in the desired directions. The procedure of space-angle signal processing is illustrated by the help of the block diagram in Figure2. Figure 2 illustrates that more IMD products can be cancelled at a specific direction if we increase the No. of circuit paths (i.e. No. of antenna array elements). In the space angle domain, the undesired IMD products are not suppressed, it just reradiates at different angles. Figure 3 shows an array pattern with illumination angles labeled according to which modulation product adds in phase at the receiver. The center lobe is the backscatter direction.

II. Experimental setup & Measured Results

Signals at the receive antenna in Figure 1 are converted to the 0 to 20 kHz baseband output of an instrumentation receiver without automatic gain control and 100 dB noise floor to clipping level dynamic range. Figure 4 depicts the single diode modulator and the 4-element array scatter inside the anechoic chamber. Figures 5, 6 and 7 show the output spectrum plots of the received signals for a single scatter, a two element scatter, and a four element scatter respectively. The modulation sidebands are symmetrical around the down converted illuminating signal and harmonics of 700 Hz out to the 5th are significant, as shown in Figure 5.

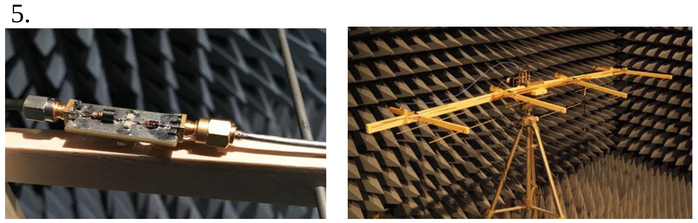

Fig. 4. single diode modulator, and 4-element modulation scatter array.

Figure 6 shows the received signal baseband spectrum from the 2 element array with 0 and 90 degree phase modulation. Note that the lower sideband is suppressed, but the lower third harmonic sideband is enhanced. Similarly, the upper third harmonic sideband is suppressed. This is expected, as the third harmonic phase is 270 degrees (3x90). Figure 7 shows measured suppression of the lower sideband and 2nd harmonic components. 2nd harmonic suppression occurs both above and below the CW illumination, as the second harmonic multiplication results in 0 x 2, 90 x 2, 180 x 2 and 270 x 2 products at the four array elements.

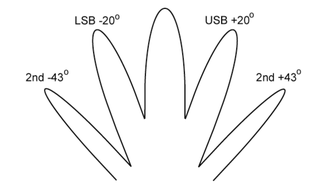

Fig. 3. Array pattern θ showing the illumination arrival angle that results in summation of the USB, LSB, upper and lower 2nd order products.

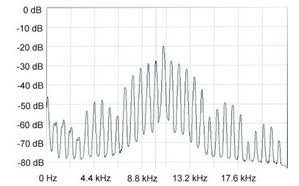

Fig. 5. the received response of a a single element

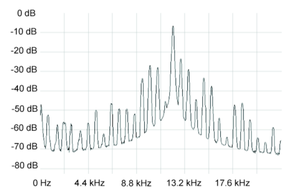

Fig. 6. the received response of a 2- element array

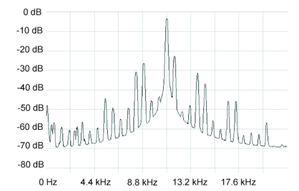

Fig. 7. the received response of a 4- element array

III. Conclusion

This necessarily brief treatment of early results with arrays of modulated scatters at UHF shows the practicality of this concept. From basic Fourier Theory the advantages of arrays with more than 4 elements are evident, and our ongoing work is at higher frequencies where such arrays are practical in our anechoic chamber. The desired output signals are added in space, without the need for electronics, waveguide, or transmission lines.

IV. References

1. M. Roche, *et al*, "UHF Reflection Coefficient Modulator Array Element," IMS 2018, accepted.
2. N Alkhafaji et al., "Space-Angle Signal Processing using a Modulated Scatter Array, IMS 2018, accepted.